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XIV.—*On the Bore, or Rushing Tide, in the Gulf of Cambay, and at the entrances of the Máhi and Sábarmatí Rivers.*

By Lieut. R. ETHERSEY, Indian Navy. Communicated by the Bombay Geographical Society.

THE Gulf of Cambay lies between $21^{\circ} 5'$ and $22^{\circ} 17'$ north latitude, and $72^{\circ} 19'$ and $72^{\circ} 51'$ east longitude; it is seventy-two miles long, and varies considerably in breadth. At the entrance between Vaux's Tomb and Gópnát'h Point it measures thirty-two miles across, which in a distance of ten leagues narrows, between B'aróch Bar and the island of Perím, to eight miles; it then opens out again to nineteen miles, between the entrance of the Dhádar River and Bhaunagar on the Káthwár coast; this space, with the exception of three channels, is occupied by extensive shoals. The Gulf contracts again to ten miles between Góngwá and the western coast, on the same parallel with a remarkable spit of land which has formed within the last twenty years. Sand-banks extend from the shores on either side, which leave a channel between them towards the centre of the Gulf from three and a half to four and a half miles wide.

From the head of the Malacca banks* in lat. $21^{\circ} 10'$ N., to the parallel of Lóhára, a point on the northern side of the entrance of the Narbadá River, in $21^{\circ} 38'$ N., the Gulf is, with the exception of the Bhagwá Sands,† clear of shoals, with irregular soundings from eight to thirty fathoms; but above this parallel it is filled with extensive shoals and sand-banks, having several deep channels between them, all of which are liable to shift, particularly during the rains. These channels all take a northerly direction, and the two principal ones unite in $22^{\circ} 7'$ N. and $72^{\circ} 36'$ E., a little below *G* on the plan, forming a channel three and a half miles wide, the greatest depth of water in this channel being six fathoms; it takes a north-easterly direction, runs close past Cambay Creek, from which it crosses to the south-eastward, and enters the Máhi River.

Another channel extends in a winding direction from the Sábarmatí River close past the Amlí Creek, from whence it keeps pretty close to the shore, and joins the main channel in about $22^{\circ} 9\frac{1}{2}'$ N. below the Bore rocks; in both of these channels the flood-tide makes with a bore or wave, caused, wherever it is observed in this gulf, by a rapidly flowing tide forced through a narrow obstructed passage.

* Lieutenant Ethersey, in addition to his survey of the Gulf of Cambay from Diu Island, along the Kát'híwár Coast, around the head of the Gulf, and down its eastern shore as far as Surat, has lately examined, in detail, these extensive shoals, and thereby rendered an important service to hydrography.—ED.

† So called from Bhagwá, a village on the north bank of a small stream called the Sená River, which takes its rise at Segwá and Sehván.

The rivers which empty themselves into this gulf are the Narbadá, Dhádar, and Máhi,* from the eastward; the Sábar-matí from the north; and the Bhádar, or Gómá, from the westward: the three latter only can have any effect on the Bore, which, in the fine season, is trifling, as the discharge from them is then very inconsiderable; for the channel opposite Dehwán, on the north bank of the Máhi, is only 300 yards wide, a few inches deep, and the stream scarcely perceptible. Again, at the small pagoda marked *H* in the chart, in $22^{\circ} 24' N.$, on the east bank of the Sábarmatí River, the channel at low water is only 150 yards wide, with a mean depth of two feet, and the stream is too weak to be ascertained by the log.

The tides throughout the Gulf are extremely rapid, and their rise and fall very large; the whole coast is low, overflowed for some distance inland at high spring-tides, and intersected by numerous small creeks and inlets.

Its situation being such as to receive the full force of the tide-wave coming from the southward and from Díú Head, the south point of the peninsula of Gujerát, lying between the Gulfs of Cambay and Cutch, along the Kát'hiwár coast, together with its peculiar shape, will, I think, sufficiently account for the strong tides which are experienced here; for at Perim, twenty-six miles from the entrance of the gulf, the stream is forced through a space four times less than it occupied between Vaux's Tomb and Góp-nát'h Point; and again, at *G*, below the Bore rocks, thirty-two miles further north, it flows into a channel only one-ninth of its original width, being not quite half of its breadth at Perim; from which circumstances the velocity of the tide is not only considerably increased as it flows towards the northern parts of the gulf, but the water is also forced up to a higher level.

The eastern or principal bore rises five miles to the west-south-westward of Cambay Creek, and is not perceptible in the neap-tides without the previous spring-tides have been very high, when it may be observed slightly through the quarter. It generally commences when the springs begin to lift; the wave increasing daily in height, as the tides gain strength; and it is at its greatest height about two days after new and full moon; it also varies with the night and day tide, because the higher the tide the greater is its velocity; and as the two tides differ from six to eight feet, and the flood of both runs the same length of time, the highest tide must have the greatest velocity, and hence the wave of the bore will be highest with the greatest tide; the night tide both of new and full moon is the highest.

By a reference to the chart it will be seen that the channel

* Vulgó, M'hái.

between the Bore rocks and *A* on the eastern sand-bank is quite clear, and free from shoals. It is four miles and a quarter wide, and the greatest depth six fathoms, where I found the velocity of the tide to be as follows, the direction being N.E. and S.W. :—

		K.	F.	Rise and Fall.
High Springs	{ Flood	6	0	33 feet
	{ Ebb	7	2	
Ordinary Springs . .	{ Flood	4	4	25 "
	{ Ebb	6	2	
Neaps	{ Flood	3	6	18 "
	{ Ebb	5	0	

From this point (*A*) the channel begins to narrow with a decreasing depth of water, until at *B*, seven miles higher up, it is only 550 yards wide, the greatest depth of water being seven feet. It is at this point that the tide first rises in a wave; when the flood makes, this may be seen running along both sides of the sand-banks, and it soon spreads across the channel, rapidly increasing in height; for by the time it passes *C*, a distance of not quite one mile and a half, it is nearly as high and has as great a velocity as it attains in any part of its course. From *C* it runs close to the high cliffs as far as *D*, spreading entirely across the channel, and rushing along with a loud roar. The small sand-bank which commences at *D* turns it to the southward of east; and when abreast of Cambay Creek it is divided into two parts by another sand-bank, the most considerable of the two, taking a south-easterly direction towards the south bank of the Máhi River, and continues on this side as far as *E*, where it crosses to the north bank, near Dahwára, close to which it pursues its course to the village of Dehwán, where it is entirely broken and interrupted by a number of sand-banks, but proceeds several miles further up, although with greatly diminished height and velocity.

The other part of the divided stream runs to the eastward, and is soon exhausted, there being no free channel for it, and the banks are greatly elevated with gradual slopes, over which it flows very slowly.

The following data show the result of my observations on the ordinary spring-tide on December 24, 1836, between the point *C* and Cambay Creek; the highest part of the wave being three feet and a half, its velocity nine knots, which was the utmost strength of the tide after the bore had passed :—

H.	M.	K.	F.	H.	M.	K.	F.
0	5	after	3 6	0	30	after	6 0
0	10	"	5 7	0	40	"	7 0
0	20	"	4 4	0	50	"	6 2

Seven knots was the strongest.

The flood ran three hours: the rise and fall of the night tide

was twenty-three feet; that of the day tide sixteen feet six inches; giving a difference of six feet six inches.

During the first hour the rise of tide was fifteen feet; in the second, six feet; and in the third, two feet.

In the first hour the water rose six feet during the first ten minutes, which will give some idea of the rapidity with which the tide rises.

January 7, 1837.—Very high spring-tide, nearly up to the mark of the tide in the rains; between the point *C* and Cambay Creek the highest part of the wave rose six feet, and its velocity was ten knots and a quarter, the strength being as follows:—

H.	M.	K.	F.	H.	M.	K.	F.
0	20	after	4 6	0	50	after	8 0
0	30	„	4 6	1	00	„	7 0
0	40	„	7 6	1	20	„	6 0

The flood tide ran three hours and two minutes. The rise and fall of the night tide was thirty feet eleven inches, the day tide twenty-three feet; the difference being seven feet eleven inches.

	FT.	IN.
Rise of tide during the first hour . . .	18	4
Ditto „ second hour . . .	8	4
Ditto „ third hour . . .	3	6

The ebb tides run steadily, but do not acquire their greatest strength until more than half-tide has passed, when the high banks are uncovered, and the stream is confined to its proper channel.

Jan. 10, 1837.—Near the village of Dehwán, on the north bank of the Máhi, the highest part of the wave was seven feet, and its velocity ten knots. The rise and fall of the night tide was twenty-two feet; but by the mark of the tide on the shore, this was one foot lower than it had been a day or two before, which is too trifling to have diminished the effect of the Bore. I was not able to measure the rise of the tide here, having no convenient place to erect a scale; it ran only two hours fifty minutes; the greatest velocity of the flood was seven knots, and the ebb six knots two furlongs.

The Western Bore is so nearly similar to that just described, in almost every particular, except its direction and effect, that a very few additional remarks will be sufficient to point out the small difference between them; and even that would have been superfluous had I not found a very great alteration in the banks and channel subsequently to my former report.

I found that from 700 to 1300 yards of the western shore had been washed away through the whole space from *I* to the east point, which is 1300 yards farther south than its former position; the bank all along, being a sandy cliff, continues still to fall with

such frequency, from the action of the tide undermining it, that, in a short time, the coast will be quite straight from the Amlí Creek to below that which is now the east point. Tons of this sandy bank are detached from the shore at one time, and these masses continue to fall into the water at different parts in such quick succession, that the report sounds at a distance like heavy artillery; the top of these cliffs, at two-thirds ebb, being from eighteen to twenty feet above the level of the water.

Again, the high sand-banks to the eastward of the Amlí Creek, which were only partially covered by the neap tides, have been swept away; nothing but low sand-banks remaining in their place, and the channel leading to the Sábarmatí River, which before took a N.N.E. direction from Amlí Point direct for that river, now turns to the N.N.W. at Amlí Point, and runs along the shore close past Amlí Creek, where it turns to the N.E., for the Sábarmatí River.

The Bore on this side is now greatly diminished, the cause of which will, I think, be evident, when it is considered that formerly, instead of the whole force of the tide setting, as at present, to the N.E. past the Bore rocks, it took a N.N.W. direction, below the above rocks, right into the Western Channel, which is only now fed by a portion of the tide from the main stream.

At present the wave of the Bore on this side, as on the other, is not perceptible as formerly at the neap tide, but is confined to the springs, at which time it takes its rise at *F*, where the channel is only 150 yards wide, with three feet of water in it; its course is close to the shore as far as *B*, where it turns, and has to encounter a stream running at the rate of two miles an hour. I found its height here increase to four feet. After passing this, the channel widens a little, having low sand-banks, which the water spreads over, the wave decreasing to one and a half and two feet, and continuing at this height past the Amlí Point, where it again runs close to the steep bank, and increases to three feet; it thus rushes along until it comes near to the Amlí Creek, where it has to encounter a stream of two knots and a half, and, in consequence of the channel's turning, its whole force is directed to that part of the high sand-bank marked *b*, where the wave was five feet; after passing this, it gradually diminishes to a few inches, for the banks are very low and the water so shallow that it can scarcely be called a channel, so that the tide is not confined, but flows over the banks in all directions. It forms again, however, at the entrance of the Sábarmatí, where the highest part was two feet: it continues its course (from this to one foot and a half) nearly to *H*, one mile past which it is lessened to a few inches.

Dec. 9, 1836.—Between *b* at Amlí Creek and Amlí Point, the highest part of the wave was five feet, its velocity eight knots and

a half. The velocity of the flood tide after the Bore had passed was as follows:—

H.	M.	K.	F.	H.	M.	K.	F.
0	10	after	3 2	0	50	after	5 6
0	20	„	4 7	1	00	„	5 4
0	30	„	4 4	1	20	„	5 0
0	40	„	5 0				

Rise and fall of the night tide, twenty-eight feet; day tide, twenty-one feet two inches; the difference being six feet ten inches. The flood ran three hours and five minutes.

The velocity of the wave was ascertained by measuring a distance from two to three and a half miles in those parts where the waves ran close to the shore, and noting the time it took to go from one station to another by a good watch. The height of the wave off Cambay, Delwán, and the Amlí Creek, was ascertained by a pole, having feet marked on it, and in other places by estimation. The velocity of the flood was measured by the common log-line and glass—the patent log being of no use, from the irregularity of the stream, as it would only have given a mean rate.

I have given the greatest heights of the wave during each spring tide; but this does not continue to be the same throughout its course, being affected by several circumstances, which cause it to vary at different distances; for instance, at those points marked in the chart *a a a*, in the Máhi, and *b b*, on the western side, where the bank is steep, forming a concave, and the stream is strong, while the direction of the Bore is towards the steep bank, the wave at these points will be greatly increased, in consequence of the force of the tide being directed to one point, as well as by the resistance of the stream. It is at these places that the wave frequently flows quite perpendicularly, having the appearance of a wall, when it curls and breaks with a thundering roar.

In those parts of its course, where the sand-banks are low on both sides, with a strong stream running in the centre (which is the case in several parts on both sides), the middle part of the wave will be retarded, and increased in height by the resistance of the ebb; while towards each side, which is out of its influence, the wave proceeds with undiminished velocity, the whole forming in a crescent shape across the channel.

By the foregoing observations it will be seen that the tide does not attain its full strength until forty or fifty minutes after it has made: it is until that time very irregular, coming with a sudden burst, with great velocity, and then decreasing again slightly. The tide never attains the same velocity as the wave of the Bore; why this is the case I am not able to determine.

In *February*, 1835, in order to try the effect of the Bore on a large-sized bander boat, and at the same time to ascer-

tain the strength of the stream after the wave had passed, at spring tide I anchored the boat half a mile to the northward of what was then the last cape on the western side of the Gulf, and it proved a more dangerous experiment than I had anticipated; although I anchored in five fathoms, the boat grounded at low-water, and was left high and dry. A few hours afterwards, the noise of the Bore was heard, when every precaution was immediately taken for the safety of the boat. The night was still and calm, and its roar, as it approached, echoing among the neighbouring cliffs, was truly awful. It struck the boat, lifted her, and threw her violently round on her bilge; in which position she was forced before it, broadside on, for the space of five minutes, the grapple being of no use, for it was carried faster than the boat. I fully expected she would go to pieces, so violently was she shaken. However, no accident happened; for, on getting to a hollow in the sand-bank, which was quickly filled, she righted, much to my satisfaction. About twenty minutes after this I hove the log, and found the stream running seven knots and a half, at which time the boat, I think, could not have been driving less than two knots and a half per hour, which would make the velocity of the stream ten knots. This I did not think too great; for, although calm, the water frequently came over the boat's bows.

Additional Observations on the Remarkable Tides in the Gulf of Cambay. By Captain THOMAS BEST JERVIS, E. I. C. Engineers, F.R.S.

THE situation of this gulf at the extreme north-western limit or angle of the Malabar coast, and consequent accumulation of the head wave at flood tide, propelled, as it is, through a comparatively contracted channel, are the immediate causes of the singular influx of the tide described in Lieutenant Ethersey's paper. The Orinoko, the Indus, and the Ganges, present similar phenomena, though the height or head with which the bore rushes into these rivers is considerably modified by their respective situations, and the directions of their principal channels. The gulf of Cambay is, in point of fact, the great or common outlet of the whole of the waters of Gujarát, which are discharged by seven principal streams; the Šábarmatí, the Máhí, the D'hádar, the Nurbhuddá,* and Taptí, and on the Káthi-wár coast, the Bhádar or Góma river, and the Gaílá, which are better known as the Dhólará and Bháónuggur rivers, these

* The orthography of the names of places is *not* according to the system usually adopted in this Journal.